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AND

PLACER DEPOSITS.

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THE FORMATION OF GOLD NUGGETS AND PLACER DEPOSITS.

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THE origin of gold both in placer deposits and in veins, and especially the origin of nuggets, has been the subject of repeated discussions and investigations which have been recently brought to my attention by several extremely interesting specimens brought to me for examination, and more especially by the one exhibited at the meeting of the Institute in February, 1880.* In the year 1874 I made some examinations of the hydraulic mines of California, and was very much struck with the distribution of the gold throughout these deep placers, which were almost invariably poor on the surface, while gradually growing richer towards the bed-rock. The constant presence of fossil-wood, and the large quantity of organic matter contained even low down in these beds, was also remarkable. Not being satisfied with the various theories advanced to account for the formation of these deposits, I began an investigation early in the year 1879 on the conditions of solubility of gold and the causes of the loss in working gold ore in a large way. The researches which I have undertaken show that gold must be considered a soluble rather than an insoluble metal, and that the conditions of solution are such as will be found anywhere where gold is likely to occur, and the solution may take place even under the ordinary circumstances of surface drainage, and may be going on freely even where the presence of gold has never been suspected, and that there are causes enough in nature to produce the solution of the gold in sufficient quantities to account for all the phenomena of both the vein and placer formations.

The general theory with regard to the formation of these placer deposits and nuggets has been that they were the result of the destruction of pre-existing vein-matter, which does not accord with the facts as shown in the deep placer deposits. The gold in such case would be distributed in layers of unequal richness throughout

* Transactions of the American Institute of Mining Engineers, vol. 8, p. 451.

the bed, the richness depending on the amount of deposition taking place at any one time, and would not occur in increasing richness from the top to the bottom. Further, every particle of gold of whatever size would have a rounded form, resulting from its abrasion against the harder rocks, which is not the case, the small as well as the large grains being of very irregular shape. It must also be borne in mind that most of the veins from which the gold is supposed to have come had a gangue of quartz. The gold is much softer than the rock; the quantity of precious metal contained in the vein would also be very much less than the rock, so that in the destruction of the formations there would be a very small amount of gold being abraded and ground in a very large quantity of rock. It is therefore likely that the coarse particles of gold, which is so much softer, would be comminuted at least as fine as the rock, and the smaller ones much finer than the rock, so that the difference in density would hardly tend to make a concentration by any subsequent action of wind or water, since the small particles of gold would tend to float away and thus prevent the concentration. Where the large particles are not in sufficient quantity to make an extended natural concentration possible, and where the deposition of the sediment of the rivers is taking place, the result would be a very small quantity of almost impalpably fine gold, distributed uniformly in a very large amount of comminuted rock, or a production of clays resembling that used to make brick around Philadelphia, which contains very small amounts of gold uniformly distributed through it. The structure, too, of each one of these particles would be the same as that of the rock with which it was abraded, and would be uniform. It is, however, well known that the grains of gold found in the placers are not uniform ; some of them are flattened with rounded edges, others rounded, and most are mammillary, all of which forms are not probable, and hardly possible, under the conditions suggested. A nugget rounded like a water-worn pebble is a great exception in any of the placer deposits.

While the theory of vein destruction might in some cases account for the presence of gold in small quantities throughout the sands in grains large enough to admit of concentration, it could never account for the presence of large nuggets, which if they had been transported any distance by water would have lost their mammillary form. Admitting the greater size and force of the ancient rivers, it is impossible to conceive that such large and irregularly shaped nuggets as those from Australia, Siberia, and from this country could ever

have been so transported by water as to be entirely relieved of all their gangue, without having themselves assumed much more regular surfaces and a more uniformly cobble-stone shape. On the other hand, slow accumulations from solutions of varying strength and a deposition of unequal rapidity continued for a great length of time, accounts perfectly both for the form and for all the attendant phenomena. It is a fact, moreover, that very large masses such as these nuggets have never been found in veins, and are confined exclusively to placer deposits. The detrital theory accounts still less for the fact that in many of the deposits, especially where the bed-rock is soft and porous, the gold often enters it to the depth of nearly a foot, and it is frequently the richest part of the deposit.

In 1867 Mr. Wilkinson, of Australia, made a series of researches with reference to the effect of organic material on the deposition of gold. Sonstadt* also made a series of researches on the presence of gold in sea-water, and found it to be present in the ratio of about one grain to the ton of water, or about $1 for every 25 tons of water.

Up to this time gold had always been considered as a very insoluble substance, because it was insoluble or very nearly so in most mineral acids. Ingenious metallurgical processes based on this insolubility have been invented, and are still in constant use; but it does not follow that because gold is not affected by the ordinary acids it is therefore not soluble in other substances much more likely to be found in nature. The action of organic acids and of the alkalies were left out of view, and also the fact that the solution of infinitesimal quantities may acquire great significance in a geological sense.

Bischoff found that sulphide of gold is slightly soluble in meteoric waters, and much more soluble in a saturated solution of sulphuretted hydrogen in water. It has also been ascertained that chloride of gold in minute quantity in an alcoholic solution may remain in solution in the presence of proto-salts of iron, and that metallic gold is slightly soluble in solutions of the per-salts of iron. But the theories founded on these discoveries supposed that gold was much less soluble than it really is, and that the solution required peculiar agencies and a set of circumstances not likely to occur everywhere. Its diffusion in sea-water was accounted for by the presence of chlorine, iodine, bromine, and of alkalies, and these conditions were not thought to be of general application in the explanation of the phenomena exhibited in mineral veins.

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* Chem. News, vol. xxvi, p. 159; Am. Chemist, vol. iii, p. 206.

Mr. Selwyn, the government geologist of Victoria, proposed a theory of solution to account for the formation of nuggets and placer deposits, suggesting that the gold was dissolved by the waters which filtered through the soil, was carried in solution until it met some nucleus around which it could deposit, and was then precipitated, and that nuggets and placer deposits were formed in this way. He does not, however, state what he supposed the cause of the solution to be, and suggests that the gold is undoubtedly deposited on particles of gold previously existing in the sands.

These researches and theories however did not attract very much attention, and the old theory of the destruction of pre-existing veins was still adhered to. It is to be observed, however, that when gold does come from the destruction of veins the surfaces are rounded and worn smooth, as is shown in the large boulder of quartz containing gold detached from a vein in Venezuela, which is now in the collection of the School of Mines. This is in entire contradiction to the mammillary structure of the nuggets. If they had been transported far by water they would have been rounded and water-worn to much more regular surfaces. These worn surfaces would of course have been confined entirely to the outside of the nuggets, any cavities existing in the interior of the piece would have been in the condition in which they left the vein, and the edges of any crystals found there would have been sharp; while in the nuggets the mammillary form exists even in the cavities of the interior, and even where crystals or the commencement of crystallization is observed, the edges of the crystal are very often blunted or rounded, showing both deposition and solution on these edges.

It is also to be noticed that the analyses of nearly all the samples of gold taken from veins show it to be much less pure than the nuggets found in the placer mines of the same district. If the gold of the placers had come from eroded rocks it would be of the same composition as that of the veins of the district in which it was found. It is well known that most of the gold nuggets are pure, while the gold of the veins is of a much lower grade, containing considerable quantities of silver and other foreign metals. Thus the Ballarat nuggets are 992.5 fine, the Australian nuggets vary from 960 to 966; those from veins in California from 875 to 885; in Transylvania 600 with 399 of silver, and in Nevada there are some of 554 of gold and 429 of silver, and others only 333 of gold with 666 of silver.

It must be remembered also that the violence of the old placer

currents was very much greater than that of the ordinary streams of these days. The rivers were not only larger and deeper, but more rapid, and the results of their action would have been an almost complete comminution of the gold by its rubbing against the harder rocks. If this were the whole of the process and no further action had taken place, the gold would be found in the sands in this comminuted condition exclusively, and few if any of the particles would have escaped the battering and pounding process incident to long exposure to rolling rocks, and the deposits resulting from it would be found on the bed of the stream.

Gold is, however, also found as nuggets, and in small particles in rocks which have never been disturbed from their original positions, but which have been decomposed to a considerable depth, and it then has the same rounded form, occupying positions which make it evident that it must have been formed *in situ*, and never have undergone any abrasive action. The nugget found in 1828, in Cabarrus County, N. C., which weighed 37 pounds, and also the one found in the Valley of Taschku Targanka, near Miask, in Siberia, which weighed 96 pounds, were both found under such circumstances in a decomposed dioritic rock. In some few cases it has been definitely ascertained that the gold has been dissolved and precipitated in the decomposed rocks, for it has penetrated only just so far as the decomposition has allowed it, the yield in gold ceasing entirely at the point where the rock allowed no further filtration; while in other rocks of a more porous nature in the same district the gold has penetrated to a depth not yet ascertained. Such a condition of things is not uncommon in the gold belts of the Southern States.

Admitting that heavier masses of gold did exist in the veins disintegrated by the ancient rivers, gravity alone cannot account for the bottom deposits (which are often 300 feet from the surface) being the richest. It would have required greater agitation of the earth than we have any evidence for believing ever took place to sift the coarse particles even through 50 feet depth of earth, and there is no indication that these deposits after they were once made were ever disturbed. It is undoubtedly true that in shallow placers, where the bed-rock comes near the surface, the surface-soil is rich; but it is the invariable rule that in the deep placers the richest deposits are near the bed-rock, and at a great distance from the surface.

There is a tradition, which is prevalent in all the gold mines of the South, and in those of some other districts, to the effect that gold *grows*, so that every few years the tails of the old mines are re-

worked, generally with a profit; the quantity separated each time, according to the local tradition, being in proportion to the length of time the material has remained undisturbed. As there is no opportunity for the gold in these sands to accumulate by gravity, the people of the region believe that gold grows like a plant.

It would not, however, be rational to deny a theory so easily explained as the formation of placers by the destruction of vein-matter without having some other to replace it. If the theory of the destruction of pre-existing veins is not tenable, we are bound to examine carefully whether there are causes in nature sufficient to account for solution, and what are the agencies that render the gold soluble. A series of experiments have been made on this subject lasting over many months, both synthetical and analytical, which seem to be of considerable importance in the study of the origin both of placer and vein phenomena. In this investigation most of the known salts of gold were prepared; but as the chloride is most easily made, this was made the basis of almost all the solutions. While making the chloride of gold for the solutions some sponge-gold was placed in a tube and heated in a current of chlorine-gas until the chloride of gold formed was entirely sublimed. It deposited at the upper part of the tube directly over the gold, and as the tube cooled, on the gold also in fine transparent crystals half an inch long. This tube, when cool, was closed while full of chlorine, by replacing the glass tubes by glass rods, and the joints made tight with paraffine. In five months the crystals were melted into a mass, and in a year the whole of the chloride had been transformed into metallic gold with occasional nodules of chloride through it; but the whole of it could be readily amalgamated.

In order to ascertain the effect of different organic substances on salts of gold in solution, five portions of fifty cubic centimeters each of a solution containing .50 gram of chloride of gold were treated in different ways. The first was covered with a cubic centimeter of petroleum. In the second a quarter of a gram of cork was placed; in the third a quarter of a gram of peat; in the fourth half a gram of leather; in the fifth half a gram of leaves. These solutions were put in a dark place, and were left for three months before examination. When the solution containing the petroleum was brought to the light the liquid had lost its color, and there were suspended in it a number of very fine and long crystals of gold, distributed nearly uniformly from the top to the bottom, and floating almost perpendicularly in the water. They had the appearance

of the hexagonal crystals described by Professor Chester.* As soon as the liquid was agitated they fell to the bottom. The solutions containing the cork, leather, and leaves had also been rendered colorless, but the gold had entered into these substances, replacing the organic matter, so that they were pseudomorphed into gold. The solution in which the peat was placed was also colorless, but the gold was precipitated in the form of very small mammillary masses, recalling perfectly the form of nuggets.

To ascertain the degree of solubility of gold a quantity of pure spongy gold was prepared, and placed in a variety of solutions; some of these were left exposed to the air; others were sealed at the ordinary temperature and pressure of the air for periods of from six to eight months; others were exposed to heat and pressure under varying conditions in an air-bath, arranged in such a way that the temperature could be kept constant for a number of hours at a time. Many of these last tubes burst after the liquid had acquired a tint. Of some of these the contents were entirely lost, of others a sufficient quantity of the liquid was left to test for gold.

Solutions of salt, sulphate of ammonia, chloride of ammonium, chloride and bromide of potassium in sealed tubes, after eight months gave no reaction. Heated for five hours at temperatures varying from 150° to 200° C., none of them, except the bromide of potassium, gave any reaction, and that reacted very strongly. In the sealed tubes the solution of salt, in which a few drops of nitric acid had been placed, reacted for gold; the iodide of potassium gave no immediate reaction, but when evaporated to dryness left a purple residue, soluble in bromine, which reacted for gold. Heated to a temperature of from 100° to 170° C., the iodide of potassium tube gave a reaction for gold not much stronger than the solution before heating.

A solution of commercial nitrate of ammonia, which contained some chloride of ammonium as an impurity, kept in an open tube at the ordinary temperature and pressure for four and a half months, colored the solution bright yellow, and reacted strongly for gold. Two solutions were made each containing five grams of nitrate of ammonia and half a gram of chloride of ammonium in 200 cubic centimeters of distilled water. One of the solutions was left in an open room and the other put in a dark place, and left for eleven days. At the end of that time both reacted strongly and with equal intensity for gold.

* American Journal of Science, 3d series, vol. xvi, p. 32.

Pure sponge-gold was then placed in the following solutions, contained in sealed tubes at the ordinary temperature and pressure for three months. Sulphide of ammonium produced no change and no reaction. With sulphide of potassium a black precipitate was formed, and a strong reaction for gold was given by the liquid. Sulphide ot sodium gave a black precipitate and a strong reaction for gold. Cyanide of potassium gave a yellow solution, a brown precipitate and smell of ammonia, and a strong reaction for gold. Chloride of magnesium, after nearly three months, gave a gelatinous precipitate, but no gold. Sulphate of soda, after the same length of time, produced no change and no reaction. The sulphate of copper produced no change after two and a half months.

Spongy gold was then put into solutions of the following substances, and heated for six and a half hours between 145° and 180° C. Sulphide of ammonium showed no apparent change, but reacted strongly for gold. The solution of sulphide of potassium attacked the glass strongly; it looked greenish, and the liquid reacted for gold; a black precipitate was formed, which was dissolved in bromine, and reacted for gold. The solution of sulphide of sodium acted slightly on the glass, and acquired a greenish tint; a pink film was found on the glass, and a slight precipitate was formed. This film reacted slightly, and the solution very strongly for gold; there was not enough of the precipitate to examine. The solution of chloride of magnesium attacked the glass strongly, from which scales fell, but no gold was dissolved. The solution of sulphate of soda gave a cloudy, flocculent precipitate, but no reaction for gold. Commercial sulphuric acid and solutions of sulphate of potash, iron, and manganese gave white scales, but no reaction for gold. Solutions of sulphate and nitrate of soda gave no change and no reaction. The solution of permanganate of potash produced no reaction. In the solution of cyanide of potassium the brown precipitate which was formed in the previous experiment dissolved, reducing the gold in the solution so that no gold was found dissolved.

A mixture of nitrate of silver and sulphuric acid produced no change after two months. A mixture of the sulphates of potash, iron, manganese, and commercial sulphuric acid produced no change after two months. The permanganate of potash and sulphuric acid gave a black precipitate and colored the liquid slightly pink, but gave no gold.

In order to test the effect of organic matter in solution, half a gram of chloride of gold was placed in two liters of Croton water in two large

bottles. One of these was left exposed to the sunlight, and from this all the gold was precipitated in less than a week; the other was placed in a dark room and left there; at the end of eight months a small amount of gold was precipitated. When solid organic matter was placed in the bottle the precipitation was quite rapid, and when the bottle was then brought into the sunlight all the gold was precipitated in about forty-eight hours.

To ascertain the effects of the different soils on weak gold solutions half a gram of chloride of gold was dissolved in ten liters of filtered Croton water, and made to pass continuously over the three mixtures given below arranged in glass funnels. The apparatus was so arranged that the liquid would flow drop by drop on the filters.

No. 1 contained 30 grams of quartz sand, No. 2, 20 grams of sand and 10 of soil, No. 3, 30 grams of magnetic iron sand and ten of quartz sand.

The filters were left exposed in a room where there was considerable dust arising, and where there was also the smoke from passing trains. In two days most of the gold had been precipitated in the filters, and the water had a greenish look. Half a gram of chloride of gold was then dissolved in ten liters of distilled water, and filtered in the same way over thirty grams of quartz sand, a mixture of twenty of sand and ten of soil, and a mixture of ten of sand and thirty of magnetic sand. These filters were carefully covered so as to prevent any dust settling on them, so that they were protected from all organic matter except such as was contained in them. At the end of two months the clean sand and the mixture of magnetic and clean sand had reduced a small quantity of gold (a little more in the latter than the former) in concretionary shapes, which, owing to the rapidity of the action, were not coherent, but could be crushed with the pressure of the finger. In the mixture with the soil the whole had been reduced, and was distributed through the sand as an impalpable powder, no indication of any concretionary form being observed.

The attempt was then made to dissolve gold in a manner similar to that which was supposed to take place in nature. For this purpose filters were prepared of thirty grams each of clean quartz sand; in one of these 1.161 grams of sponge-gold was placed and carefully mixed with the sand; in each of the other two half a gram of very fine gold was mixed. Over the sponge-gold ten liters of distilled water, containing thirty grams of common salt and five grams of nitrate of soda, was made to filter constantly for two months, but no

observable change took place. For the second solution six liters of Croton water were taken, in which nine grams of nitrate of ammonia and one gram of chloride of ammonium were dissolved. This was made to filter constantly for one month, but no gold was dissolved. For the last experiment one gram of nitrate of ammonia and nine grams of chloride of ammonium were used, but no gold was dissolved.

It was the intention to continue these filtrations for six months at a time, and with all the conditions of natural waters, but the difficulty of making the experiments continuous decided the abandonment of them after a number of the other results had been obtained. The failure to dissolve gold in this short time does not prove that there is no action, as the other experiments show. An amount equal to a little less than that in sea-water might easily escape detection. In these experiments there is lacking the certainty that all the conditions necessary to success will be fulfilled. It was found in one of the experiments, made in the early stages of the investigation, that the fine dust circulating in the room was sufficient to precipitate the gold from a dilute solution. All these researches had to be made in a room to which many persons had access, and it is quite possible that the organic matter precipitated the gold in these last experiments as fast as it was dissolved; for in the experiments for the production of the placers the organic matter did deposit the gold in the sand. It is greatly to be regretted that these experiments could not have been made in the complete absence of dust.

In order to test the effect of organic life in such solutions, a plant was watered with a very weak solution of gold, but as is often the case in such experiments the plant died of too much watering. In the anxiety to produce the kind of absorption by plants described by Durocher and Malaguti, the experiment was made a failure by too much enterprise. The examination of the ashes of the plant showed a small amount of gold, but most of the gold precipitated was in the soil around the plant, being thrown down there by the organic material in the earth. This experiment indicates the origin of the thin plates of gold which are sometimes found in the grass roots of certain placer countries.*

It will be observed that in almost all the cases where gold was dissolved, chlorine and some nitrogenous substances were found together in the presence of alkaline waters. These same conditions

* Transactions, American Institute of Mining Engineers, vol. vi, p. 33.

are favorable, also to the separation and solution of silica. It has been proven by these experiments that the alkaline sulphides act on gold as well as the substances enumerated above, and it is quite easy to imagine the conditions under which the gold, already in solution in excessively small quantities, coming in contact either with solid or liquid organic matter, may precipitate all the metal.

In Grass Valley; California, I have known of gold being thrown down in the filter of a Plattner's vat by the organic matter contained in the very impure water used there for the solution of the gold rendered soluble by the action of the chlorine. The filter was full of metallic gold, and there was no means of ascertaining how much of it had been lost. Several ounces of a brown deposit were taken from it which was nearly pure gold. This cause of deposition, and of loss in large operations, has, I believe, been entirely overlooked. It is quite easy to explain the presence of gold in alluvial sands by the action of sunlight alone on the waters containing the gold in solution, and to account for the gold on the bed-rock, by the solutions coming in contact with organic or mineral matter, such as the lignites, fossil-woods, or the pyrites, which is everywhere found in deep placer deposits. The waters not being able to pass the bed-rock, remain there in contact with the organic matter until all the gold is precipitated. The same would be true of the decomposing rocks, or of slaty strata coming up to the bottom of the deposit at an angle. The deposition would be rendered much more rapid by any electrical currents that might pass through the strata.

In all of these phenomena, time, which in the operations of nature is unlimited, is one of the chief factors. In any laboratory experiment the limit of time must of necessity be short, but there is no such limit in nature. That this solution goes on on a large scale there is every reason to suppose. That it may be connected with vein phenomena the California nugget shows, since in this case both the formation of the quartz and of the nugget are evidently posterior to that of the blue gravel.

It will be seen from these reactions that many of the conditions favorable to the solution of gold are also favorable for the solution of silica, and that, as Professor Kerr shows,* the rocks may be actually decomposed and the gold deposited, forming in this way shallow deposits called veins, in which the gold disappears entirely beyond a few feet.

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* Transactions, American Institute of Mining Engineers, vol. 8, p. 462.

Nothing is more likely than that the infiltration of water through rocks undergoing decomposition, of which there are enormous quantities in the gold region, should take up the alkalies, and, slowly passing over the gold, should dissolve it. The composition of these alkaline salts would depend on the nature of the rock through which the waters passed, but it is more than likely that they would be mixtures of many of the compounds likely to attack the gold and carry it off in solution, and not alkaline carbonates and sulphides alone, although these would be likely not only to be present, but to be powerful agents in carrying on the work of solution. In some cases the decay of the rocks is so rapid that the phenomena may, as it were, be caught in the act. The agencies producing the decomposition of the rock, penetrating it beyond the limits of local drainage, and carrying off the soluble parts, leave the debris in a condition easily penetrated by the infiltrating solutions, and ready to receive any deposit which these solutions may for any cause leave behind them. A source of these deposits in the deep placers of California is the trap which sometimes covers the old river deposits to a depth of 150 feet. In the deep placers these waters would be capable of holding the gold in solution until they met some decomposing element, such as particles of metallic compounds, native metals or organic matter, which is always present in large quantities in the deep placers. If a nucleus of metal were present the gold would be precipitated on it, and if none were present then the gold would come down as a powder, each grain of which, however small, would serve as a nucleus for future aggregations.

Admitting the solutions to be even more dilute than the sea-water near the coast of England, yet unlimited time and quantity would evidently produce these effects, redistributing the gold. Iodine, which is a solvent of gold, is found in many of the plants of the gold region, and in considerable quantities in sea-water. Sonstadt* supposes that gold is kept in solution in the water of the sea by the slow rate at which iodate of calcium is decomposed in the sea-water of the temperate zones, but suggests that where the decomposition of the iodate, whose presence is necessary to keep the small amount of gold in solution, is very rapid as in hot countries, the liberation of the nascent iodine, and consequent rapid solution of the gold, and subsequent precipitation by organic matter is quite sufficient to account for the great richness of the gold deposits of tropical countries.

* Chem. News, vol. xxvi, p. 161. Am. Chemist, vol. iii, p. 208.

It seems, by the experiments already cited, to be clearly proved that gold is not only not insoluble, but that in nature it is constantly being dissolved out of the rocks and placers, the waters of filtration dissolving out of the rocks in their passage through them all the materials necessary for the solution of the gold, and carrying it in very dilute solutions until it meets some substance that precipitates it. It seems to be proved that when the action is slow and localized, we have the phenomena of placers with large or small nuggets and irregularly shaped pieces, and when the action is rapid we find the gold in small particles distributed through the sands. We have reason to suppose that these phenomena are now taking place in such a way as to concentrate the gold by infiltration and precipitation in the tailings of mines which cannot be concentrated by mechanical means. Some of these phenomena can be accounted for by the simple action of sunlight, but others, mostly those of the deep placer deposits, have their cause in the large amount of organic material contained in them. The use of a charcoal filter to precipitate the gold from relatively concentrated solutions in one of the recently invented metallurgical processes, is a very suggestive idea of the means nature may have used on an immense scale on very attenuated solutions.

The same conditions which cause the solution of gold in certain cases cause also the solution of silica. This explains the phenomenon of mammillary and apparently water-worn nuggets (like that from Placer County) encased in quartz, while both the gold and the quartz have been formed posterior to the blue gravel. It also explains the presence of "putty stones," as the soft pieces of decomposed rock constantly found in placer deposits are called. Many of the causes which produce the precipitation of the gold would also produce the reduction of soluble sulphates to insoluble sulphides, the gold being retained in the mass. This would account for the almost constant presence of gold in pyrites, or the occurrence of some of the copper ores of Texas in the form of trees, the ore containing both gold and silver, and also for the constant presence of gold in the iron ores of Brazil, the so-called Jacotinga, and also for the presence of trees transformed into iron ore carrying gold in some of our Western States. In many of the deep placers of California the heavy cap of basalt is quite sufficient to account for many of the phenomena which occur not only beneath but around it.

The fact that gold has not as yet been found in potable waters may be simply due to the extreme difficulty attendant on its detec-

tion in minute quantity. It is more than likely that many of the geological phenomena on a large scale were produced by very dilute solutions or very slight forces acting for a very long time. How far the electrical currents of the earth may have been a factor in these phenomena it is impossible to surmise. It is, however, more than probable that they were the result, not of one alone, but of all the causes mentioned, and perhaps many others which have as yet escaped our attention. No single agent is so powerful a solvent of gold as chlorine. Very few drainage-waters are free from some compound of it, and no soil is without the nitrogenous materials necessary to set the chlorine free, and therefore capable of attacking the gold and rendering it soluble. The experiments show that a trace of it is quite sufficient to dissolve enough gold to color a solution so that the eye can detect it after a few weeks exposure.

In the nugget of Placer County it would have been impossible for either the gold or the silica to have got into its position except by solution. The iron of the blue gravel in this case seems to have been the first cause of precipitation, and subsequently the gold itself was an active agent in increasing its own weight. The general absence of crystals and of their rounded edges, where they are found, can be easily accounted for by the fact of the rapid action possible in the placers. The readiness of filtration through the easily permeated gravel causes the gold to precipitate so rapidly that there is no time for any but a mammillary deposit; while in vein deposits the extreme slowness of the deposition allows the gold to assume a crystalline shape. When we consider that two-thirds of all the gold produced in the world comes from alluvial deposits, it seems difficult to account for its presence in the sands in any other way than by solution.